Inmarsat London wireless	Inmarsat, a treaty based Òco-opÓ of telecom operators from 73 countries or a privatized In- marsat spin-off	$2.6 billion	2000	ÒInmarsat-PÓ system still undefined but leaning toward 12 MEO satellites to link handheld terminals
American Mobil Satellite Corp., Reston, VA	Includes Hughes McCaw Cellular Mtel and Singapore Telecom	$1.2 billion	1994	3 GEO satellites will link handheld phones in North America
Ellipsat elliptically orbiting International, Inc. Washington, D.C.	Includes Mobil Communications Holdings, Inc., Fairchild Space & Defense, and Israeli Aircraft Ltd.		$700 million	1997 16 LEO satellites for service to handheld terminals
Globalstar Palo Alto, CA worldwide	Includes Loral, Qualcomm, Alcatel Deutsche, Aero- space, Air Touch, Vodafone and Dacom	$1.8 billion	1998	48 LEO satellites to provide voice, data, paging and facsimile
Teledesic satellites to Kirkland, WA data, video	Includes Craig McCaw Develop- ment Co. and William Gates	$6.3 billion	2001	840 LEO provide global coverage for broadband and voice service

Motorola, a major player in wireless network equipment and consumer terminals, is the driving force behind the Iridium LEO system and will be in a good position to link up to other ground-based wireless access systems or the PSTN whenever complementary joint service opportunities arise. However, at a pre-announced price of $3 per minute, it is clear that Iridium is not a mass market substitute for land-based wireless access service in the NII. The Iridium handset itself is very expensive at an estimated $3,000.[50] Planned for service in 1998, the Iridium system includes about 66 LEO satellites orbiting about 500 miles above the earth and operating in the 1.5-2.5 GHz band, at a launch cost of $13M each. MotorolaÕs Iridium system is unique in that it will utilize satellite-to-satellite links to transit traffic between user locations, thereby bypassing terrestrial networks in transiting countries. Iridium will even be able to transmit direct to user handsets, but will usually make use of its domestic ÒgatewayÓ cellular providersÕ terrestrial network for call terminations or originations.

Most other proposed systems have somewhat less ambitious plans than Iridium and plan to utilize the existing facilities of terrestrial carriers. For example, Globalstar's LEO system is planning to augment land-based wireless access systems using 48 satellites and 200 earth station gateways. GlobalstarÕs handset costs are estimated at $700.[51] American Mobile Satellite Corporation, a GEO system, plans to operate a relatively inexpensive system of dual-mode satellite/cellular mobile service covering only North America and has announced target prices which are among the lowest. Based on the early price announcements, many MSS firms will be much more price competitive than Iridium. Target per minute usage charges for these MSS systems range anywhere from about $.25 to $2.00. Competition should force these prices to come closer together, probably somewhere in the middle of these estimates. Handset prices will also vary at first, but competition should also force some convergence.

Among planned MEO systems, Inmarsat, the international satellite consortium providing telecommunications service for shipping and airlines, has announced the introduction of a new personal satellite phone service called Inmarsat-P, available in the 1998-2000 time frame. Odyssey, a satellite system backed by TRW and Teleglobe, recently announced a two-way global MEO network consisting of 12 satellites orbiting about 6000 miles above the earth. This system would also plan to compete for mass market telephony services as well as niche market applications.

The Teledesic network backed by McCaw and Microsoft is an even more ambitious technological effort than Iridium. Operating in the very high frequency Ka band (20-30 GHz), these birds would be capable of providing global coverage for 2-way broadband services including video telephony and multi-media. Such projects are hugely expensive however, and, while the potential telecommunications capabilities and applications of these "superbirds" is very impressive, it is also still very experimental.

There have recently been even more global satellite systems announced besides those listed in table 4.4. Spaceway, a new all-digital satellite system proposal before the FCC made by the Hughes Communications division of General Motors is a MEO Ka band wireless access system. The proposed system, consisting of 17 satellites, would be designed to provide bandwidth-on-demand for all types of narrowband and broadband telecommunications services in competition with land-based alternatives. A novel feature of this system which allows for spectrum reuse is that an individual satellite will use transponder "spot beams," to segment the very large signal coverage area (or "footprint") normally provided by geosynchronous orbit birds. Subscribers would be connected with so-called *ultra small aperture terminals* (USAT) measuring only 66 cm across and costing less than $1,000.

With so many grandiose announcements from so many deep-pocket investors it is safe to assume that some, perhaps most, of these global satellite communications systems will eventually become operational (though some industry consolidation is likely). The investment community views the future as risky and attracting external financing has not been easy. Two of the leading contenders in the race to deploy satellite systems, Globalstar and Iridium, have both failed recently to attract investor interest in recent bond offerings, even at fairly high coupon rates.[52]

In addition to approximately 320 communication satellites already operating, satellite networks providing a wide variety of services will become a ubiquitous public infrastructure. Pelton (1994) provides estimates of revenues for global satellite service markets, which are forecast to more than triple by the year 2002. Nevertheless, even after considering the pronouncements of the major industry players, satellite services will be relegated to serving niche market applications and therefore, their role in the American NII will be limited. Perhaps the greatest potential for the new global satellite systems would be to take advantage of their relative cost performance and coverage capability to provide for modern digital telecommunications service in rural, remote, or otherwise undeveloped parts of the world.

4.8 Evaluating network costs

Comparing the economics of various alternatives for wireless access systems requires an examination of the time path of the expenditure stream and compared that to the anticipated revenues. The focus herein is on that portion of the expenditure stream which reflects the capital costs of building a wireless access network system. These costs come in several different flavors: 1) so-called first costs, or the total installed costs of the initial wireless access system upon activation; 2) build-out costs, or the costs incurred over time to expand the system coverage area to its long term target; and, 3) system growth and maturation costs or the variable costs which result from rising system usage. In the case of existing wireless access systems, there is also a difference in the costs to upgrade or otherwise modernize the system to handle new service capabilities compared to the costs associated with building a system from scratch.

The third item, the variable costs of operating the system to handle increased demand, is actually the most critical since it is the determining factor for a company's long term operating cash flow or price/cost margins. Of course, that assumes that the up-front fixed (e.g., start-up) costs of building a particular network system are not so much higher than other competing systems that the project would never get off the ground. But this is not likely when comparing alternative system costs on a per subscriber basis for a large scale urban market, in which case the high up-front fixed costs are spread over so many demand units that the average fixed cost represents a very small portion of the average total cost (the sum of average fixed and variable costs).

The goal of economic analysis is to identify and design the wireless access system which achieves the lowest investment in network facilities for a given demand level (assuming that the level of service quality is a competitive one). This usually means that, for a given market area, a network design is selected which provides area coverage for the least amount of network facilities. The network is engineered in accordance with technical network parameters (e.g., RF spectrum bandwidth, radio carrier channel size, user channel size, co-channel interference factors, frequency reuse patterns, etc.) corresponding to a particular technology (e.g., TDMA/CDMA) and network architecture (e.g., macrocell/microcell). Depending on the market area (e.g., city) to be studied, a geographic terrain and climate is assumed (e.g., flat, hilly, rainy, dry), along with assumed levels and distributions of man made RF interference factors (e.g., traffic patterns and loads, buildings). A subscriber density must also be assumed (e.g., subscribers per sq. kilometer and calls or call attempts per hour).

Based on the size of the radio coverage area, the network start-up or initial construction phase includes investments in the core network hardware and software represented by the MSC and the associated trunk network connecting to the initial number of BSs deployed. BSTs are placed to prevent unacceptable signal fading and signal propagation associated with geographic topology (e.g., lakes, rivers, hills, valleys, trees) and other physical RF barriers (e.g., buildings, tunnels, bridges). There are any number of problems associated with the lack of line of sight for the RF signals between the base stations and handsets, and considerable engineering discretion is used in solving them in any specific instance. For example, when a large building or other structure blocks a given radio transmission path, the problem may be handled by placing an extra radio antenna on top of a building or along a section of street to go around it, or even under the building by transferring the signal to underground wireline facilities.[53]

Once the network system operating parameters and assumptions are developed for any given market area and the network is engineered, the vendor equipment can be sized and priced to estimate the initial or "first cost" for building the network. First cost is also called the *engineered, furnished, and installed* (EF&I) system cost and represents the total cost of "turning up" a network system. By assuming an initial market penetration rate, the relative cost per subscriber for different wireless access systems of similar service capability and service quality may be determined.

In the case of satellite networks, the EF&I costs of satellite development and launch dominate the first costs of the system (or transponder lease costs), followed by earth station siting and construction costs. By their very nature, the initial capacities of satellite systems are huge. During the build-out phase for satellite systems, the per subscriber system costs fall even more rapidly then those experienced by land-based systems because average costs for satellite networks are more sensitive to the scale of operations. In most metropolitan land-based wireless access systems, the per subscriber system costs level out relatively early compared to satellite systems (e.g., 50K vs. 1M subscribers). This makes it imperative for satellite operators to sign up as many subscribers as possible through advance marketing programs. This is the opposite of the situation for most land-based systems, which are often more concerned with keeping up with demand early in market roll outs. In both land-based and satellite-based wireless access systems, once system build out is reached the variable capital cost of adding individual subscriber connections is quite low.

A further evaluation of the EF&I costs of different wireless access systems may be made by holding constant the total available RF spectrum and the size of the service coverage area (using the same assumed levels of terrain and man-made interference factors) and then systematically varying the subscriber density. This will reveal how different systems (e.g., CDMA/TDMA, macrocell/microcell, ESMR) perform for dense urban applications versus less dense suburban and rural applications.

The analysis can become considerably more complex by combining different wireless access technologies in all or certain portions of the radio coverage area (e.g., wireless multi-mode systems using both CT, and cellular technology). Furthermore, due to advances in digital signal coding and compression techniques, directional antennae placement, and sophisticated variable powering of handset-to-base-station signal strength to account for near/far conditions, the capacities of most wireless access systems are constantly being improved usually resulting in reduced per subscriber system costs. The different combinations of the various methods which are available to simultaneously increase system capacity and lower unit costs makes it hard to distinguish definitively which type of wireless access system can achieve the highest capacity and lowest cost per unit of available RF spectrum. Different types of wireless access systems have different methods of channel access and utilization, different power levels, frequency reuse patterns and co-channel interference factors, all of which affect the overall economics of system construction.

In another stage of the cost analysis, by systematically increasing the available spectrum per coverage area, there is the possibility for increased channel spacing and less concern about controlling co-channel interference which adds to system costs. It is useful to examine the trend in cost per demand unit for increments in available spectrum, including an examination of the resultant per subscriber costs for increasing levels of subscriber density and penetration with and without the possibility for increasing the available spectrum.

The entire study process would yield an evaluation of the relative cost and efficiency of spectrum use at various levels of system utilization. While such an approach in the abstract would clearly be preferred before the FCC decided on its spectrum allocation and licensing scheme, it can not happen that way in practice because the performance characteristics of the technology itself are so fluid. It is simply not possible to wait for the "right" wireless access method to come along before licensing spectrum since no one really knows what the "right" one is. For example, several years from now, further advancements in so-called "spread spectrum" and broadband wireless access techniques (e.g., CDMA) may reveal that the FCC's current spectrum licensing scheme of 30 MHz blocks and 10 MHz blocks, up to a total allowed 40 MHz per market area, may not have been enough to maximize efficient bandwidth utilization.[54]

4.9 Economics of wireless access

The engineering and capital budgeting analysis for prospective wireless access systems involves considerable effort and numerous assumptions about some very young technologies, all in the presence of uncertain future demand. The competitive environment and the FCC's continuing spectrum auctions have raised the stakes considerably for would-be wireless access network providers to decide now which technology to select for a market rollout. Consequently, detailed and specific engineering and financial analyses being performed in the industry are being held close to the vest. However, based on publicly available data (including that from investment houses in their efforts to calculate prospective market penetration rates and net cash flows to establish valuation benchmarks for the investor community) indications are that the state of the art in engineering economics and financial modeling of network systems is not very far along.

There are several reasons for this. First, as stated, there is a "cart before the horse" problem with the FCC setting spectrum allocations and licensing schemes before the technology of digital wireless access has progressed to the point that there is a clear indication of how much spectrum should be allocated to narrowband and broadband wireless access services. The fact that the technology is so fluid, coupled with the deadline for spectrum auction bids, puts a tremendous amount of pressure on industry players to commit now to a given wireless access technology and network architecture so that financial modeling can precede the spectrum auction awards.

Consequently, prospective wireless access system operators have had to contract with one or another equipment manufacturers to obtain bid prices for the new, (and, in some cases, untested) technology in advance of the development of production equipment. This has led most major players to set their stakes in the ground based on one preferred technology and/or equipment vendor, rendering moot the issue of analyzing the costs of alternative systems.

While it is still possible to pursue financial analysis to evaluate the relative costs of different network configurations within a chosen technology, it occurs in a much more limited context than a full evaluation across technologies. Given the FCC's announced spectrum policy, coupled with the fact that a technology choice must be made relatively quickly, the industry's network models and financial analyses are being conducted in a rather unsystematic fashion.

In the economic and financial phase of the analysis, the network engineering design is now ready for application to a dynamic capital budgeting plan in a business case setting. Once the static cost of initial construction is combined with an analysis of the incremental costs of the system build out over time, a dynamic picture of the stream of expenditures associated with a given wireless access system is sufficiently developed to make an informed decision about committing investment dollars to the construction program.

The initial system costs for wireless access network construction for land-based systems is dominated by the investment in siting and constructing the network nodes, especially the MSCs and BSCs, related hardware and software, and the trunk network required to aggregate and "backhaul" subscriber usage to the BSC and MSC. After initial system construction, the cost drivers associated with system growth during build out are the addition of transceivers (e.g., BTSs) and trunking facilities to expand system coverage and capacity incrementally.

Once build out has occurred and the system has matured, operating and marketing expense factors dominate. Usage-based interconnection charges paid to the PSTN operator will likely be a significant cost driver during both the growth and the maturation phase. Bypassing the local telco network (for example by interconnecting to a competitive access provider or long distance carrier) may be a way for a wireless carrier to avoid paying the high rates for PSTN access on the originating end of a call, but it is not so easy on the terminating end of a call where there is no way of knowing where the calls are going to terminate *ex-ante* on the PSTN.

The expenditure streams associated with the three primary phases of wireless access development (start up, build out, and maturation) can be estimated according to the time path of forecasted demand. The demand forecast is based on pricing assumptions. Since it is so difficult to forecast market penetration rates over time and total demand levels at any future point in time -- especially in what is arguably going to be a highly contentious market due to the number of participants -- sensitivity analysis to account for forecasting error is crucial. Sensitivity analysis involves randomly changing the initial demand assumptions over a range of possible values to be able to judge the potential for forecasting error to affect prospective cash flows.

Returning to the dynamics of system costs, it is interesting to note that when initial construction and build out of AMPS cellular systems began in 1984 the per subscriber costs were very high at first at $2,000-$3,000, and fell rapidly thereafter, levelizing at about $700-$1000 per subscriber with very little marketing expenses. After only ten years of being in existence, competition for customers has become fierce with the marketing expense per new subscriber now being almost equal to the total amount of current capital costs per subscriber, about $700 (making the total cost of a new subscriber about $1,400). Thus, even before the AMPS market has matured (it is still growing), the nature of the business has already been transformed from one of simply keeping up with demand to one of actually vying for demand.[55]

AMPS subscribership growth is still rapidly expanding (51% last year). But system capacities, many of which have been increased through the use of FDMA/TDMA techniques and the partitioning of cells into sectors, are generally able to handle the rising demand with little additional capital cost. This has created some very high cash operating margins from the base of cellular subscribers. This cellular experience buoys the financial outlook for future wireless access systems which are actively seeking investment dollars to build new networks.

Since new digital wireless access networks have the same fundamental cost structure as AMPS-D or GSM digital cellular systems (see figure 4.1), the per subscriber costs of new ESMR, macro and microcellular systems are expected to track along a similar time path as system construction and build out occurs, although at a different level depending on the specific features and costs of different types of wireless access systems.

4.10 Critique of the approach

The financial modeling of wireless access systems to date has focused almost entirely on static calculations of per subscriber capital costs of the stand-alone wireless network. There would appear to be at least two areas of network and financial modeling that could use substantial improvement: 1) the common assumption that all subscribers (and their associated network costs) are alike; and 2) the lack of consideration of shared trunking alternatives, including wireline network interconnection. These need to be addressed to fully evaluate the prospects of wireless alternatives.

Regarding the first point about static calculations of per subscriber average costs, there needs to be more emphasis on dynamic process models based on the pattern and level of network usage, not on an "average" subscriber. A model based on usage would better describe the underlying network engineering relationships between network components and how they vary with growth in usage. There is at least one such model, but it has not yet been applied to actual data in the US.[56]

In other words, the network model should be able to answer the basic question: As peak network usage grows, what is the incremental cost of handling that growth for each major network component (e.g., BSC, BTS, trunking, etc.)? In contrast, current models focus on a different, but related, question: as subscribers are added to the network system, what is the average cost per subscriber? The answer to the latter question may be useful, but much less instructive than the former.

The efficiency of a wireless access system to handle demand growth is best measured by incremental capacity costs caused by network usage, not the average cost per subscriber. Once a wireless access network system is built, the primary cost drivers are the additional network facilities required whenever system capacity is strained by additional usage. For any given cell site, certain system components will exhaust due to capacity constraints, causing the placement of additional antennas, transceivers, and associated trunking facilities. When cell sites themselves exhaust, cell coverage areas are reduced to expand frequency reuse causing new cells sites to be placed. It is expensive to equip entirely new cell sites. This explains the dynamic cost structure of wireless access systems.

Existing network and financial models are static and tend only to focus on spectrum and network capital costs per subscriber, or per population (in the industry jargon "per pop") for discreet levels of market penetration. Thus, the focus is on primarily fixed and sunk costs of system start up. In reality, on-going network cost drivers, which are important for determining operating cash flows, are based on two primary considerations not usually reflected in existing cost models. The incremental cost of expanding area coverage, and the incremental cost of usage. The per subscriber and per minute costs of the latter are quite different and distinct from the former; it is the time and spatial distribution of the frequency of call attempts and the calls themselves during busy periods that cause costs to be incurred. For example, the MSC is a computer that controls network usage, assigns frequencies, adjusts power levels, and controls call hand-off. In the case of calls from or to roaming units (meaning away from the home base station area), there is more work involved to complete calls because the MSC must interact with a network database and intelligent network system, which may or may not be located at the MSC site. The remote transceiver sites similarly must transmit calls between the handsets and the BSC using subscriber radio channels and trunking facilities.

All of the major components of wireless access systems have an operating capacity that is sensitive only to peak period usage; it is the exhaust of the available capacity which defines the trigger point for incurring additional network investments necessary to relieve that exhaust. Thus, it would be useful to view the cost of the total network and its major components as varying with usage levels. Contrast this to the common approach of current network models that assume an average usage level (in industry jargon, erlangs per subscriber), and then assume that as subscribers are added, network usage increases exactly in proportion to the existing base of subscribers. In addition, the assumed amount of usage per subscriber is a small fraction of that used in standard wireline models of thetelephone companiesand is usually based on what is known about mobile cellular subscriber usage.

This is somewhat unrealistic. What is known from the mobile cellular experience is that early subscribers tend to be heavy users of the service because they value it more and are willing to pay high prices and can afford higher total phone bills. Later subscribers joining the system during system build out, value the service less, are willing to pay less, use it less, and tend to roam less. Since all network costs are usage sensitive and since different users have different usage patterns, this cannot be reflected in the type of broad averages assumed in current studies. A richer analysis would build costs from the bottom up by taking usage and roaming costs and assigning them to types of users. User demographics (e.g., high use/low use, roaming/not roaming, moving fast/moving slow) naturally varies from one market area to another or even within market areas by BTS location. Models based on actual usage characteristics would be better able to reflect the impacts on system capacity and costs from adding subscribers and/or calls. Hence, to the extent that there is a difference between usage and subscription rates, the former should be tied to the demand forecast which drives the economic cost model in a business case.

Furthermore, the use of an average historical usage rate per <u>mobile</u> system subscriber would not be expected to be representative of the actual usage one would eventually expect from an average wireless <u>access</u> system subscriber. Wireless access will be cheaper to use and more versatile than mobile access and therefore per subscriber usage will be higher. Wireless access is suitable for all modes of portability. It is therefore more useful and convenient in both portable and stationary situations compared to cellular mobile service. Eventually wireless access is going to become a substitute for fixed wireline telephone service. This would call for assumptions of higher usage levels than those being assumed in current cellular models, but somewhat lower than monthly network usage levels associated with flat rate local telephone service. The reason is that wireless access systems will offer more features and similar quality, but lower prices and more convenience than mobile cellular systems.

In fact, it is entirely possible, if not probable, that eventually wireless usage levels per subscriber would actually grow to levels higher than that associated with current local telephone service. The reason is that the added convenience of communicating anywhere, anytime, with anyone, would increase the overall propensity to communicate. It is well known that telephone usage begets more usage -- how many times do you play telephone tag or need to follow-up on a call? That is some time away however if wireless access network operators plan to charge for usage and do not offer flat rate options like local telephone companies. Consumers like flat rate options for local phone service and have experienced many decades of satisfaction with it. Flat rate wireless pricing may already be getting started; the first digital PCN operator (Mercury--UK) has a zero usage price in off-peak periods.[57]

To summarize the point, the focus of current cost models on per subscriber capital costs requires a host of somewhat unnecessary assumptions. Fundamentally, the primary cost drivers of a wireless access system are based on usage. Changing the modeling approach to capture and reflect the costs of increasing capacity incrementally on the network system would yield a much more realistic operating scenario for capital budgeting and business case analysis. In this costing approach, a clearer picture of the cash flow from wireless system operations is developed. Increasing demand for wireless access and usage, or both at once, translates into an increase in certain portions of the engineered capacity of the system (e.g., advancing the placement of BTSs, expanding capacity of traffic aggregation and trunk and backhaul facilities), and increases revenues incrementally as well.

Another area for improvement in wireless access system models is to model explicitly the cost of PSTN network interconnection and shared trunking arrangements. The cost of PSTN interconnection could be incurred per minute or per interconnecting trunk and should be included in any financial analysis since it will be, in most cases, an unavoidable incremental cost of usage growth, whether for call originations or terminations. This raises an important strategic issue for wireless network modeling. If a wireless access system operator must incur interconnection costs to the PSTN, why not plan to interconnect at the most convenient and cost-minimizing way? Very little explicit modeling of local PSTN joint service arrangements has occurred to date, but could be an important source of cost savings to new network operators.

A primary driver of incremental cost for wireless access systems involves aggregating and trunking traffic among remote radio nodes (BTSs/BSCs) and between those nodes and the central nodes (MSCs). There are also the network control functions which may require trunking to and from a centralize database. Instead of the standard assumption of a stand-alone wireless access network system, including trunking facilities, why not consider as a strategic alternative the sharing of network facilities owned by incumbent wireline carrier networks, like telephone companies and cable television companies ? Interconnecting to, and leasing capacity on, the ubiquitous intelligent networks employed by PSTN operators or other *competitive access providers* (CAPs) has the potential to reduce substantially investment costs in stand-alone facilities of the wireless access network.

4.11 Public policy for wireless networks in the NII

A number of public policy implications flow from the preceding discussion and analysis in key areas: NII market structure and spectrum allocation, network compatibility standards, interconnection and access pricing, common carriage and universal service.

4.12 Market structure and spectrum allocation

The Administration's stated objective for the NII is to have a competitive market as the vehicle to drive investment in the telecom sector. The FCC has certainly followed suit by allocating RF spectrum to foster at least three major players in the market for so-called "broadband" PCS wireless access services. This is in addition to new and expanded allocations to true wireless broadband service providers such as wireless cable and satellite systems.

Whether intended or not, the FCC's spectrum allocations of up to 40 MHz for individual licensees of PCS services effectively preclude them from the two-way broadband services market. If wireless is to someday serve the mass market for multi-media or video telephony, it will have to come from wireless cable and satellite service providers or some combination of these and other land-based systems, perhaps coupled with in-home wireless systems using unlicensed spectrum (e.g., infrared). As wireless technology progresses and as the government can be convinced to let go of more of the fallow frequency spectrum, the role of wireless access may be expanded considerably over that already planned with PCS networks.

The FCC can facilitate this process by extending its new-found "flexible use" policies beyond the relatively small amount of PCS spectrum to a much wider range of spectrum encompassing existing licensed bands, starting with those broadcast frequencies that appear to have greatest potential for two-way service in a digital environment (e.g., wireless cable) and those which are underutilized (e.g., UHF TV). Revisiting the reasonableness of old licenses and the old spectrum endowments could not only bring more money into the government coffers, it would also expand competition and investment in the NII. In adopting its flexible use rules for PCS and allocating unlicensed spectrum at no cost to new service providers, the FCC has begun to move down the right path. Hopefully it will continue the journey.

4.13 Network compatibility standards, interconnection and access pricing

Critical to the success of the NII and the role of local wireless access services within it is the ability to offer convenient nationwide calling capability. Wireless access systems could someday provide the ability to call *anyone*, *anywhere*, *anytime*. Similar to what has already occurred for narrowband ISDN standards, national and international coordination of network compatibility is crucial to the success of a technology and a public infrastructure. Rules for governing both the wireless network interface and user network interface to the PSTN must be agreed upon by the industry players. The government's role is to establish a fair process to see to it that the industry sets a reasonable standard in a reasonable period of time. It is the voluntary nature of standard setting and the compliance process that will minimize the risk of adopting an inferior standard or having no standard at all.

Pricing for network interconnection and access to the PSTN must be nondiscriminatory and competitively neutral. During the transition to full competition in all aspects of the PSTN, regulations regarding cost-based, nondiscriminatory tariffs for PSTN interconnection is essential to assuring a level playing field for entrants and incumbents alike. If such rules are developed and enforced, then there is no reason to restrict in any way competition between incumbents and entrants. The FCC's licensing of wireless PCS and broadcast spectrum allocations are biased against incumbent operators so that direct competition for local telephone service and television will develop. This should be a temporary measure until nondiscriminatory pricing rules for PSTN access and interconnection are adopted. Otherwise, legitimate economies of scope from technological integration of network operators in the NII may be unduly delayed or foregone altogether, to the ultimate detriment of consumers.

The cost of new wireless technology is primarily driven by the portability demands of the calling party and secondarily by the requirements of locating the called party wherever they are. This means that the success and the cost of achieving portability critically depends on network interconnection. Even when the called party is not on the move, wireless network interconnection to the PSTN is critical to successful call completion.

Since new wireless access systems are predominately competitive local operations providing services to the public for random call originations, it will be very difficult to successfully avoid paying for call terminations on the PSTN because it simply cannot be known where the calls are going to end up. Bypassing the local PSTN operators for call terminations to avoid paying network access charges has always been problematic, even for major national long distance companies. It will be a very long time before the various competitive wireless access companies will be able to successfully piece together national bypass arrangements on both the originating and terminating portions of calls. This situation would require that most Americans use wireless access and that there is very close service coordination among what are ostensibly competing local companies. While some national wireless consortiums with national spectrum licenses will claim to be able to provide "seamless" national service, there will invariably be a need for local interconnection for some (probably most) calls.

Depending on future regulatory rules concerning pricing for interconnection, PSTN access charges are potentially very substantial. The imperative of the Administration's NII policy--that wireless or other private networks interconnect or are otherwise compatible with one another and the PSTN--is well founded. The cost and price of that interconnection within the context of the NII has yet to be directly addressed. If the government truly wants to solve the interconnection problem for new wireless access operators, it will require some creative plans to gradually reduce the PSTN interconnection tariffs. A system of cost-based rates for PSTN interconnection will substantially improve the financial prospects of new competitive wireless access networks, and, at the same time, will level the playing field between incumbent localtelephone companiesand new entrants. The transition to non-discriminatory cost-based PSTN interconnection charges will not be easy because it involves reforming the current system of cross-subsidies to basic local exchange services, but the process must begin soon to eliminate artificial barriers to entry to new technologies like digital wireless access.

The most obvious economic solution to achieving both a competitive market for local telephone service and low cost interconnection would simply be for the government to quit regulating local market entry and, at the same time, deregulate rates. This would [redacted] ignoring the mass market of residential subscribers. In such situations, a sort of red-lining could occur due to private market incentives to discriminate in the name of profit opportunity rather than any conscious avoidance of serving certain neighborhoods.

Universal nondiscriminatory access to the PSTN is part and parcel of the tradition of regulated common carriers in the US. On the other hand, private contract carriers like cable television companiesand wireless systems have neither the obligation nor the inclination to provide service in very thin rural and remote locales. The available cost data indicates that the financial health of both wired and wireless access systems is strongly and directly related to subscriber density. This is not true for satellite systems, however, which depend more on total system demand without particular regard to where the demand is coming from. Thus, satellite systems of the future may be well suited to provide universal coverage in rural and remote areas because they do not feature the very high subscriber connection costs that land-based network systems do. Within the context of the NII, it remains a matter of public policy as to whether or not the level of service via two-way digital satellite systems for rural and remote areas is acceptable and comparable to the level of service provided by land-based urban systems.

In light of this and the fact that the NII policy generally prefers private market solutions to public assistance programs, perhaps the FCC should consider a rural area policy that provides certain benefits to those network operators willing to serve remote and rural subscribers that otherwise would not be able to obtain access to the NII without a government subsidy.

In the case of telephone companies serving rural areas, the FCC typically relaxes rules restricting PSTN operators to allow them to provide wireless services within their monopoly local service areas by granting them waivers to use spectrum normally reserved for competitive entrants or to use spectrum normally reserved for other uses, but which lie fallow in rural areas.

If the current state of cellular mobile service in rural areas is any indication, the Commission may need to do more. This could be done, for example by extending spectrum rights to regional licensees serving metropolitan areas to encourage them to extend their coverage area, perhaps in conjunction with the rural PSTN operator using toll connect trunks back to the urban center. Beyond allocating more spectrum to rural radio services, the FCC could tailor its system powering restrictions to meet the needs of rural operators. Radio system interference is less likely in rural areas than in dense urban areas. An increase in the allowed power levels of rural radio systems will increase the coverage area per antenna site thereby improving the financial viability of rural wireless systems.

Barring success with such policies, as a last resort, the government may choose to subsidize PSTN network upgrades in rural areas under a related NII initiative.

4.15 The politics of the NII

The important message for public policy is that, until the service requirements of the universal NII have been specified, the question as to which is preferred, wireline or wireless access service, cannot be answered. If, as many believe, the NII only contemplates socially efficient access to narrowband digital voice and data services, then digital wireless technology is preferred for dedicated subscriber connections to the wireline intercity PSTN. The fact that wireless access costs are lower notwithstanding, the real bonus for the consuming public from this scenario is portability.

If however, access to broadband service, especially bandwidth-on-demand type access service, must be added to the narrowband service mix for the NII, then wireline access technology is likely to be the winner in the race for preeminence in the future NII.

There is an interesting irony which flows out of this conclusion: acting in their own business interests, wireless access network providers of all types, narrowband and broadband (e.g., wireless cable and satellite services), would not want to back a definition of service for the NII that included broadband capability. If they did, the long-term winner in the race to be the infrastructure network provider is likely to be wireline access.

By promoting a narrowband access infrastructure, narrowband wireless network operators would be the least cost alternative, and digital wireless broadcast networks would also be the least cost alternative for the traditional (huge) niche market for one-way video service.

Thus, if the social cost of infrastructure is the issue for the NII, and if policy makers envision bandwidth-on-demand as a long term infrastructure imperative, integrated two-way broadband services are best provided by wireline operators (e.g., cable television companiesand telcos). In this scenario, even though the role of wireless access services in the NII is not a dominant one, the indisputable convenience aspects of portability coupled with the affordability of new wireless technology will assure that the mass market will still be served by the interconnected adjunct networks of wireless access operators.

This conclusion leads to another interesting twist for the public policy stance of the wireless industry regarding the NII. By voluntarily opting out of the government NII juggernaut, wireless network system operators may actually be selecting the right path. After all, the NII concept implies government interference in such critical areas of universal service and so-called "carrier of last resort" obligations, common carrier regulations for pricing, standards and network interconnection; none of which apply to private contract carriers, which is what many new wireless carriers are planning to be. Since wireless technology has inherent cost and market advantages (e.g., portability, convenience) over its wireline counterpart, its importance in future consumer markets is virtually assured and there may be relatively little to be gained by the wireless industry becoming one of the tools of the federal governmentÕs regulatory competition policy in the NII. New digital wireless carriers also run the risk of encountering burdensome state regulation if they are similarly used by state governments as a tool to bring competition to the market for local telephone service.

The bottom line for wireless technology, whether preferred by policy makers for the NII or not, is that it will be around and it will develop and thrive in the mass market. Considering this inescapable conclusion, and considering that the private sector tends to be very distrustful of government involvement in a an otherwise competitive business, wireless network operators of all stripes might consider it a blessing that they are not tagged as the vehicle for driving onto the public information superhighway.

Chapter 5

5.0 System Costs and Functionality

The costs and functionality of wireless access systems can be compared to their wireline counterparts in order to assess their prospective roles in the future information infrastructure. There are numerous existing studies of the costs and capabilities of digital wireline access systems using fiber optic, coaxial and copper cable.[1]

Fiber-to-the-home (FTTH) systems are the "cadillac" of wireline access systems because of the cost performance and virtually limitless bandwidth offered by an all fiber optic system. As discussed in Chapter 3, *fiber-to-the-curb* (FTTC) refers to a wide variety of network systems. Wireline FTTC systems employ fiber optic cable in portions of the shared trunk network, connected to copper and/or coaxial cable to complete the connection between the subscriber's premises and the network node or switch. While there are many different FTTC systems employing a wide range of novel network architectures and proprietary features, all must conform to a generic interface to the *public switched telephone network* (PSTN).

5.1 Summary of Wireline Network System Costs

A survey of wireline system costs on a per subscriber basis is presented in table 5.1. The costs shown are estimates of initial network construction costs. These costs, also referred to as *installed first costs* (IFC), are the costs required to procure the network system components, install the system and make it operational. The costs estimates presented in table 5.1 are the *long run average incremental cost* per subscriber which, assuming that system capacity is fully utilized, is defined as the total project cost (or IFC) divided by the number of subscribers. In reality, due to the high up front fixed costs of installing network systems, the average system costs per subscriber will fall as more and more subscribers come onto the system until the engineered system capacity exhausts. Long run average incremental costs reflect the steady state of average costs per subscriber and is also a good estimate of the incremental cost per subscriber of system capacity growth. Chapter 6 provides a detailed discussion of state of the art costing methods.

Table 5.1 Wireline system cost on a per subscriber basis

	TYPE OF WIRELINE SERVICE
AVERAGE INCREMENTAL COST PER SUBSCRIBER	
BASE CASE CURRENT COST	Plain Old Telephone Service (POTS)

	$1,000	AIC of New Telephone Network Access Line
	$700	Plain Old Cable Service (POCS) AIC of New Cable Network Access Line
NARROWBAND ISDN (N-ISDN)	100-200	N-ISDN telephone company access line upgrade
	$300-500	N-ISDN upgrade including digital switch placement
MEDIUMBAND DIGITAL SERVICE	$500-700	Asymmetrical Digital Subscriber Line (ADSL)

FIBER OPTIC NETWORK ACCESS LINE UPGRADES

Fiber-To-The-Home (FTTH)		Telephone Company (FTTH) for POTS only
	$3,000+	
		Future (1998-2000)
	$1,000+	
		Telephone Company FTTH (two-way broadband)
	$5,000+	
		Future (1998-2000)
	$2,000+	
		Cable Network FTTH (N-ISDN + two-way broadband)
	$1,500+	
		Future (1998-2000)
	$1,000+	

Fiber-To-The-Curb (FTTC)	Telephone Company (FTTC) for POTS only
$750	
	Telephone Company FTTC (POTS+POCS)
$1,350	

Cable Hybrid Fiber/Coaxial Network for POCS only
$50-100

Cable Hybrid Fiber/Coaxial Network for POTS+POCS
$200-300

The costs for narrowband and broadband digital networks in table 5.1 represent the per subscriber cost of upgrading subscriber access lines for telephone and cable networks. *Customer premises equipment* (CPE) costs are not included. The costs presented are based on many industry sources and generally represent the consensus view. For purposes of comparison, table 5.1 also provides benchmark estimates of current average incremental costs for existing telephone (POTS) and cable television (POCS) networks using traditional analog technology. Note that these benchmark costs are *total* incremental costs per subscriber, not the incremental costs associated with a network upgrade.

As indicated in table 5.1, telephone company access line upgrade costs for broadband FTTH or FTTC systems are much higher than those for narrowband systems (i.e., N-ISDN).

The cost estimates in table 5.1 also include a "mediumband" technology called *asymmetrical digital subscriber line* (ADSL). ADSL is a modem based technology which uses sophisticated *digital signal processing* (DSP) techniques to increase the telecommunications capability of standard two wire copper telephone lines. ADSL provides a two way channel for narrowband digital telephony integrated with one way "mediumband" service to support "video dial tone" and "video on demand" services (technically a 1.5 Mb/s downstream channel for single channel VCR quality video service). Applications of second generation ADSL offer increased bandwidths up to about 640 kb/s upstream and from 4-19 Mb/s downstream--enough for several digitally compressed video channels. ADSL subscriber connections will be limited to a distance of about 12 kft. Third generation systems will offer even more bandwidth, but will be limited to subscriber connections of very short distance.

Table 5.2 provides the average incremental costs for wireless network systems. As in the case of the wireless access system cost estimates provided in Chapter 4, except for satellite systems, the wireless system costs presented in table 5.2 do not include the cost of CPE or the additional costs (in the case of all non-PSTN network operators whether wireline or wireless) represented by payments to local telcos for interconnecting to the PSTN to achieve ubiquitous service capability. The current (substantial) prices charged by incumbent local telephone companies to other carriers for PSTN interconnection (so-called "access charges") can easily dominate the on-going costs of operating a new digital network system. Thus, per subscriber capital investment costs notwithstanding, the level of PSTN access charges can drastically alter the financial prospects (if any) for new digital network operators. Data is not generally available for the current or forecasted costs which must be borne by wireless operators for PSTN interconnection.

Table 5.2 Wireless system average incremental cost per subscriber

WIRELESS SYSTEM		CAPITAL COSTS PER SUBSCRIBER
CURRENT AMPS		$700 - 1000
PCN/PCS		
Macrocell Environment	AMPS-D (TDMA)	$300-500
	CDMA	$350 (for urban system with over 50,000 subscribers)
Microcell Environment	TDMA	$500
	CDMA	$500
WIRELESS CABLE	MMDS(television only	$350 - $450 (50% CPE and 50% installation) $525 ($380 reusable is subscriber discontinues service)
	LMDS (television only)	$40 (cost per urban home passed) $110 (cost per suburban home passed) $700 (CPE cost per subscriber)
	Two-way MMDS, LMDS	Not Available/Experimental
SATELLITE	DBS (television only)	$300 - $800 (includes CPE)

Table 5.2 summarizes the per subscriber wireless access system costs presented earlier in Chapter 4. When comparing the relative cost and effectiveness of wireline (table 5.1) and wireless (table 5.2) access systems, there are certain major inherent differences that must be accounted for if an apples to apples assessment is desired. First, on the wireless side, there is the unambiguous advantage of portability that simply cannot exist with the wireline alternative.

On the wireline side, there is the inherent advantage that the technology is potentially capable of providing for a fully integrated interactive broadband system. As previously stated in Chapter 4, it is not reasonable to assume that wireless access will be able to serve as an integrated broadband system capable of bandwidth on demand applications for everything from voice to video telephony. This is not to say that it is not possible because indeed it is. It is only to say that the spectrum allocations and licensing schemes of the FCC do not allow for it in the context of known wireless access systems.

Digital wireless technology may still become a formidable competitor to integrated broadband wired networks for providing full service broadband capability to the mass market. Now that the FCC has granted LMDS system operators the ability to provide narrowband two way radio telephone service in competition with the traditional wired POTS service of incumbent telcos, the fortunes of wireless access systems as full service infrastructure networks may be changing for the better. With 1 GHz of usable spectrum, LMDS system operators have enough potential radio spectrum to provide a full range of digital narrowband and broadband services to the mass market on the same network system. However, line of sight issues remain a unique problem for serving everyone within the radio coverage area of the LMDS transceiver.

With its large slice of bandwidth, LMDS is unique. Other cellular operators with licenses to a slice of "broadband" radio frequency spectrum, like *commercial mobile radio service* (CMRS) providers, are limited to 40 MHz of "broadband" spectrum. This paltry amount is not nearly enough to provide broadband multimedia service to a mass market.

5.2 Narrowband NII Access

Thus, an apples to apples comparison of wireline and wireless access systems would have to eliminate infrastructure options requiring either broadband services alone, or integrated network systems for broadband and narrowband services. This leaves two relevant options for infrastructure wireless access systems: 1) narrowband digital data and POTS; or 2) a combination of one-way "distributive" video and digital data and POTS.

Limiting technological options in this way sheds some light on the wireless vs. wireline debate. Based on the cost data from tables 5.1 and 5.2, wireless access for narrowband data and POTS is clearly preferable to wireline access. This is not surprising considering the obvious differences in system construction costs (e.g., the high cost of laying a physical cable circuit versus placement of an antenna at the subscriber location). Even if the IFCs of wired network access systems were the same as those for wireless systems, the long term cost advantage would still lie with the wireless alternatives because in a wireless environment much of the network system costs are "fungible" in the sense that they are available for reuse if a given subscriber chooses to terminate service. Furthermore, a major portion of wireless access system costs are not committed until a subscriber requests service installation.

5.3 Broadband NII Access

What about access for one way broadband services, or for the combination of one way broadband, POTS and digital data services? Here, the results are somewhat mixed, but tend to favor the wireline alternative.

In the case of stand-alone video systems, both hybrid fiber coax systems and their wireless counterparts (e.g., MMDS, LMDS, DBS) are fairly closely matched in terms of total cost per subscriber. Again, however, the wireless operator has a lower "sunk" network investment, and a more variable capital cost structure. As would be expected, the per subscriber costs for the physical distribution network are somewhat higher for the wireline alternative, while CPE costs are somewhat higher for the wireless alternative. However, this does not account for potential declines in future wireless CPE costs (or network distribution costs for that matter). Because cableco and telco networks are ubiquitous, R&D and manufacturing efforts have concentrated on new digital equipment and devices for use in conjunction with wired networks. That will change as digital wireless access networks are deployed more ubiquitously.

Since the future market for digital interactive multimedia is not particularly concerned with one way video service, the relative costs of wired and wireless video distribution systems will not be discussed further, except to point out that digital satellite systems are a cost effective alternative to wired cable systems for broadcast video service. Were it not for wired cable's huge head start in the market, satellite video systems would likely be dominating the mass market for entertainment video service. Terrestrial wireless cable systems (MMDS, LMDS) also enjoy a cost advantage over wired cable systems and are even cost competitive with satellite systems.

The more important comparison for the future multimedia environment and the new information infrastructure is between wired and wireless technological alternatives for the combination of two way narrowband digital service and one way broadband video. Now the wireline alternative seems to have the cost edge. The cost of upgrading a wireline broadband video distribution network (e.g., CATV) to provide narrowband two way service is somewhat lower than the cost of adding a two way wireless capability to a the wireless video network (satellite or wireless cable), even without incurring the costs of physically integrating the narrowband and broadband service on the same radio access link. The reason is that, in light of planned spectrum allocations, there do not appear to be many system cost efficiencies from integrating PCS and broadcast video services on the same wireless network access system. On the other hand, there do appear to be cost efficiencies from such integration on the wireline side.[2] It is important to note that this conclusion presumes that the broadband wireline operators themselves (e.g., cablecos) do not have to incur the cost of a narrowband switching capability. In other words, the wireline access company is just that--access. The switching capability would be provided by interconnection to the PSTN, thus avoiding the fixed capital investments associated with the switching function. A cableco's PSTN interconnection arrangement, necessary to obtain a switching function and ubiquitous call completions is not likely to come free, but that is also true for wireless cable and satellite systems desiring to provide telephone services. Competitive telecommunications companies simply will not be viable as infrastructure network providers without achieving the capability of ubiquitous call terminations, and this invariably requires PSTN access and the costs that go along with it.

Interestingly, the conclusion that wired video systems have an advantage over their wireless counterparts when being upgraded to provide narrowband two way services does not necessarily hold true for the situation where a wireline POTS network is upgraded to handle one way video services. Upgrading a narrowband telephone network to include integrated wireline video service may not be cost effective relative to a non-integrated approach whereby two way narrowband digital service continues to be offered on a separate network, and broadband video on a wireless one.[3] It is possible that this is the reason that, until a lower cost more mature technology comes along to integrate video with the telephone network, large incumbent local telephone companies are investing heavily in non-integrated wireless alternatives like wireless cable and satellite networks.

Thus, based on the available data, it is safe to conclude that, in the future, wireless access systems (i.e., wireless cable and satellite) will be the preferred technological choice (i.e., most cost efficient method of providing *dedicated* subscriber connections to the PSTN) for either stand alone digital video network systems or for digital narrowband services. If this is so, why aren't they being used as such? The answer is simply that the technology is too new; but, over time, this will change, and wireless alternatives will begin to displace their wired counterparts.

This conclusion does not necessarily hold for network facilities which are shared among a number of subscribers and among a number of narrowband and broadband services. In those cases, it is a close call between wireless and wireline technologies. However, once sharing of network facilities reaches a very high level in a multi-node network, like the PSTN trunk network, the calculus dramatically shifts in favor of wireline (i.e., fiber optic) trunk connections.

The importance of this is that, until the service requirements of the universal information infrastructure of the future have been specified (or are otherwise discovered via the market